Renewable Energy Technologies for Use on the Outer Continental Shelf

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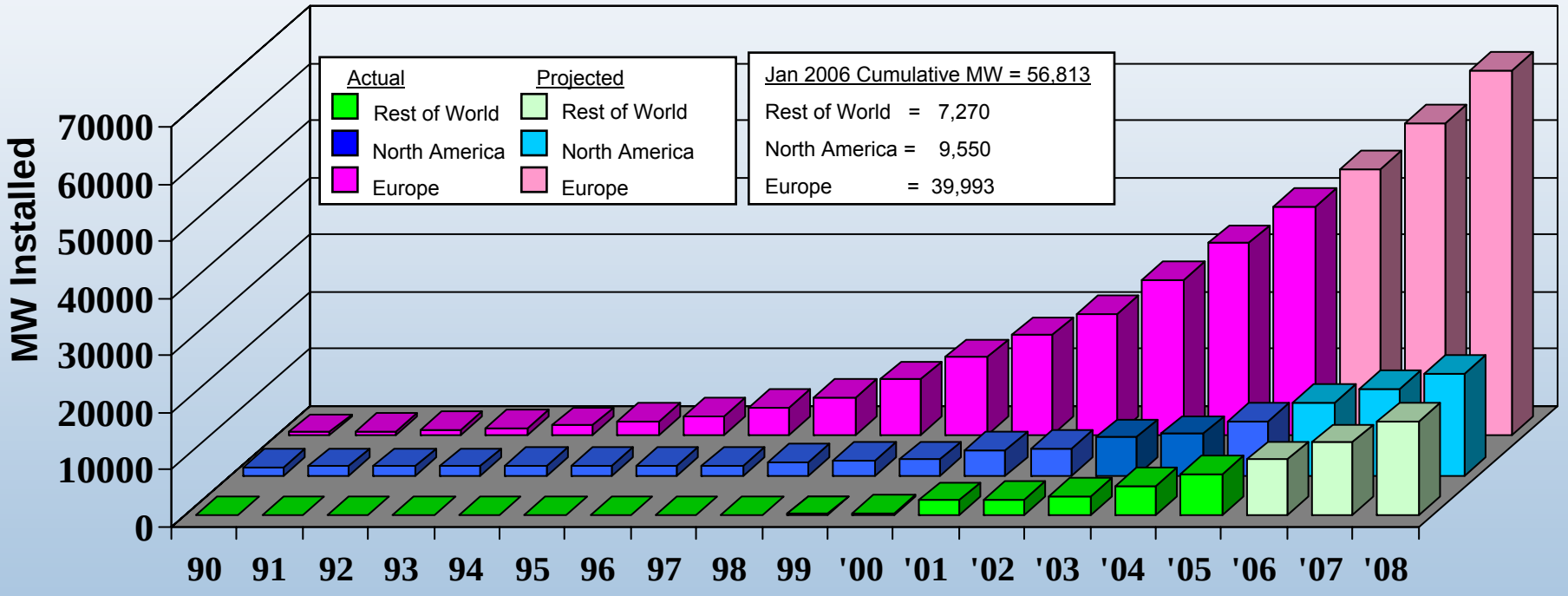
Technology Overview

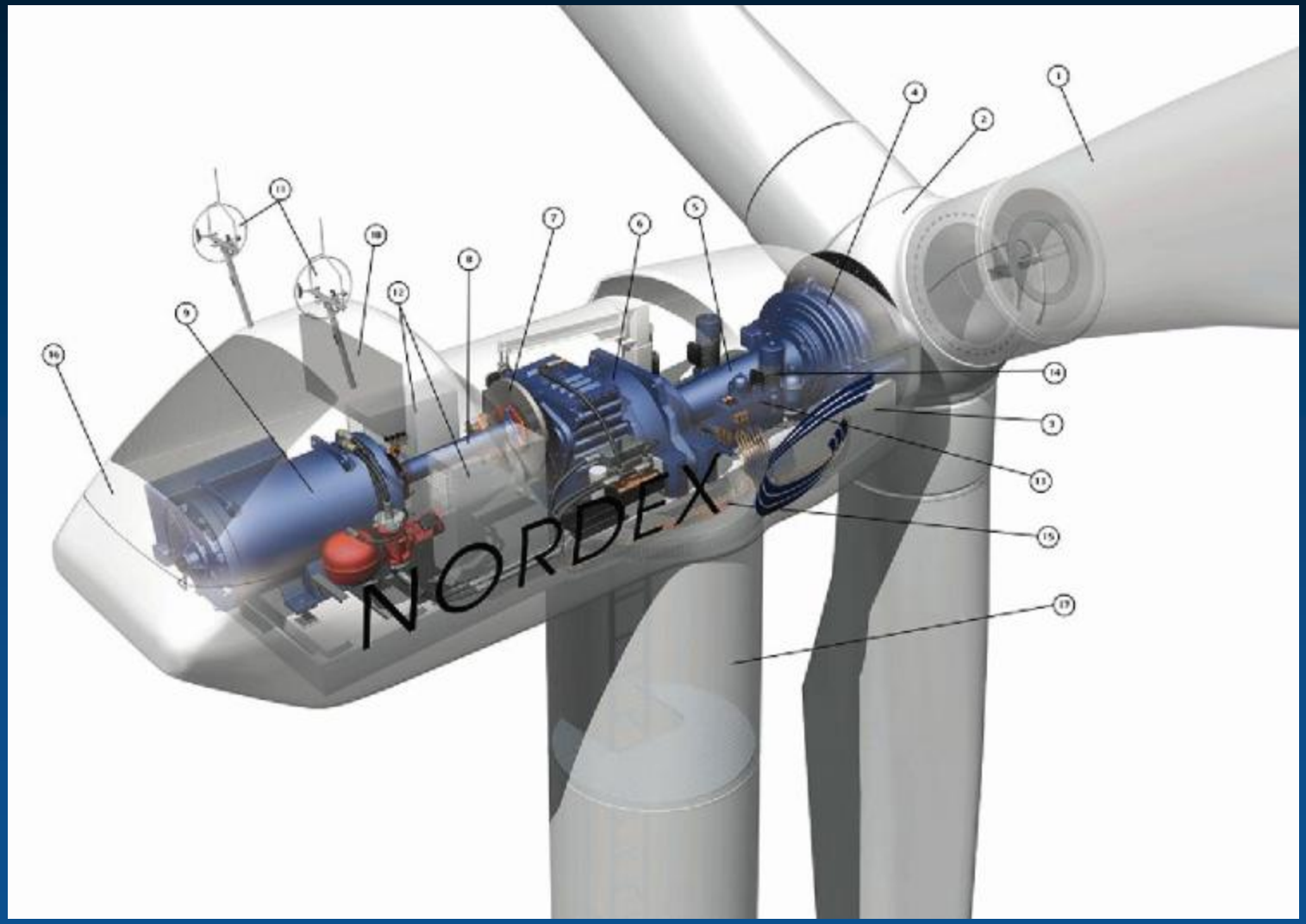
- Offshore Wind
- Ocean Wave
- Ocean Current
- Ocean Tidal

Growth of Wind Energy Capacity Worldwide



Sources: BTM Consult Aps, Sept 2005
Windpower Monthly, January 2006

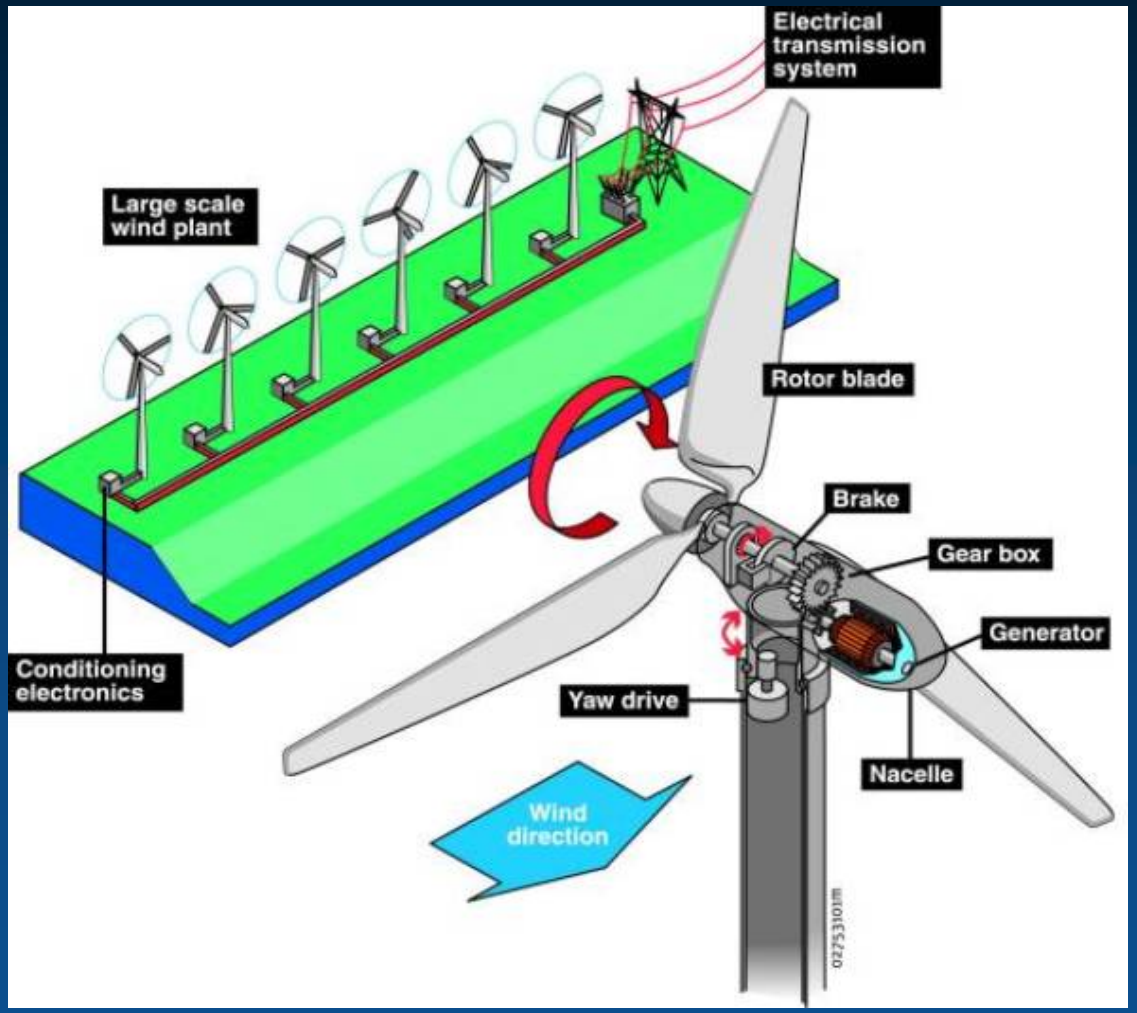
A Typical Large Turbine has Multiple Subsystems and Controls



Schematic of Wind Plant

At it's simplest, the wind turns the turbine's blades, which spin a shaft connected to a generator that makes electricity.

Large turbines are grouped together to form a wind power plant, which feeds electricity to the grid.



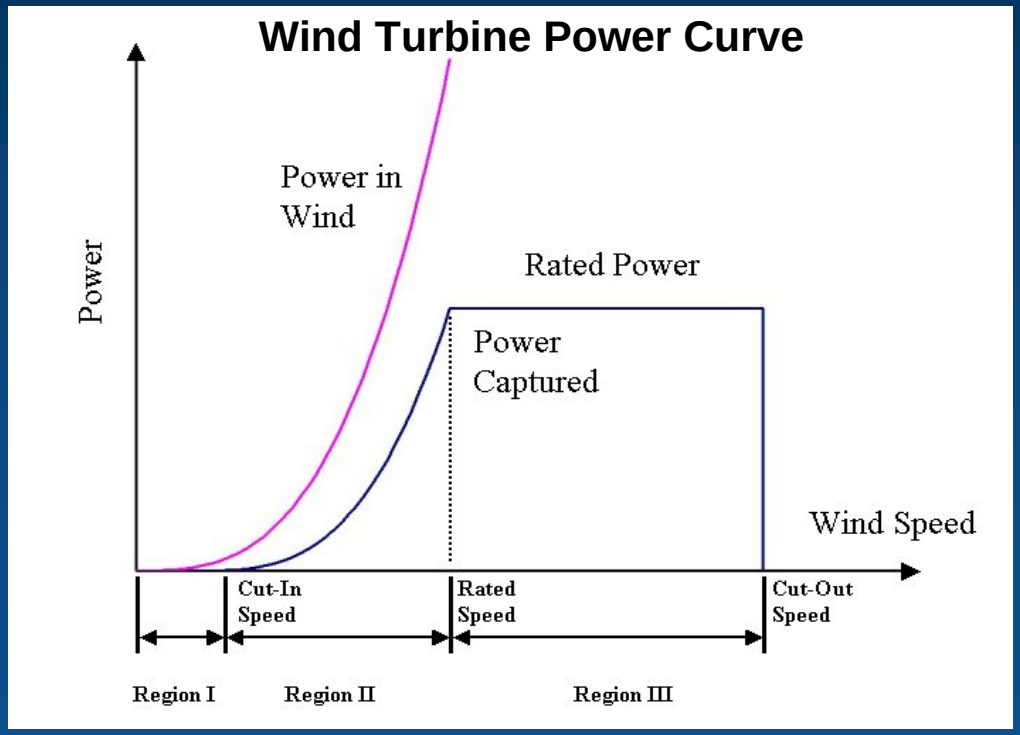
Wind Turbine Power Basics

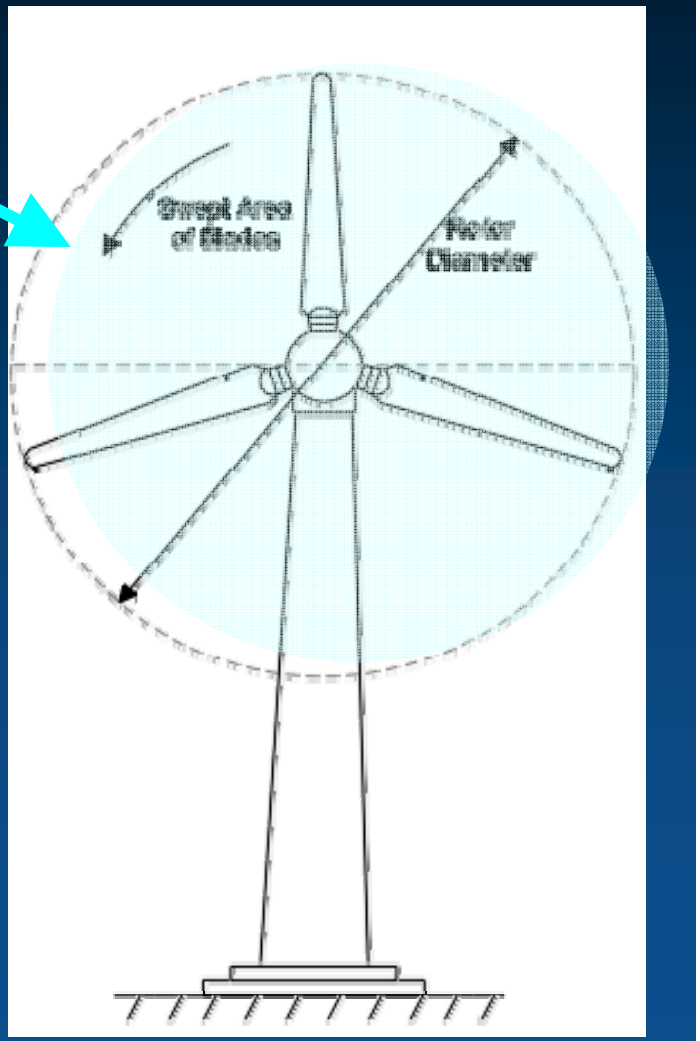
Power in the Wind = ½ρAV³

A - Area of the circle swept by the rotor

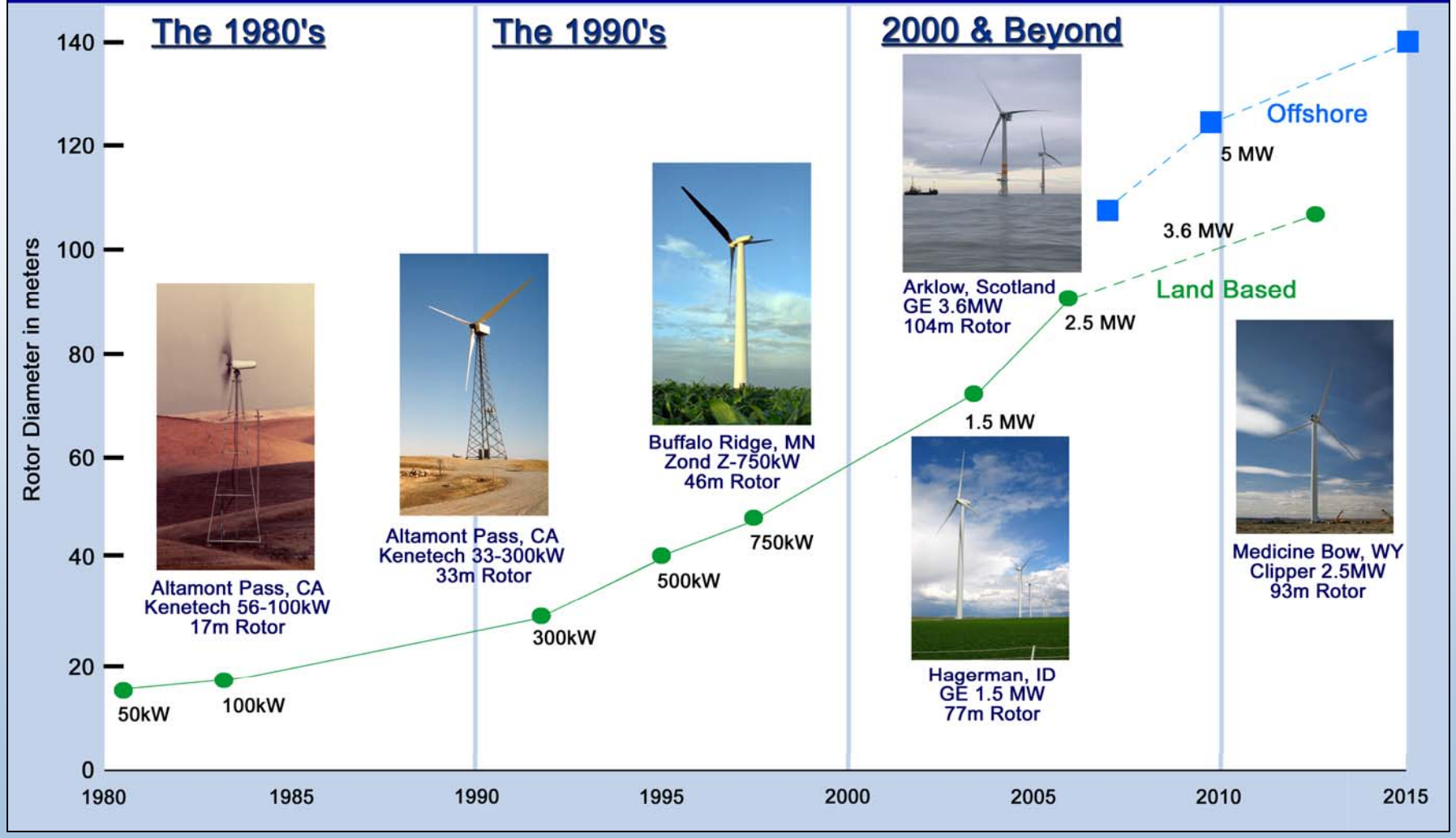
ρ = Air density

V = Wind Velocity

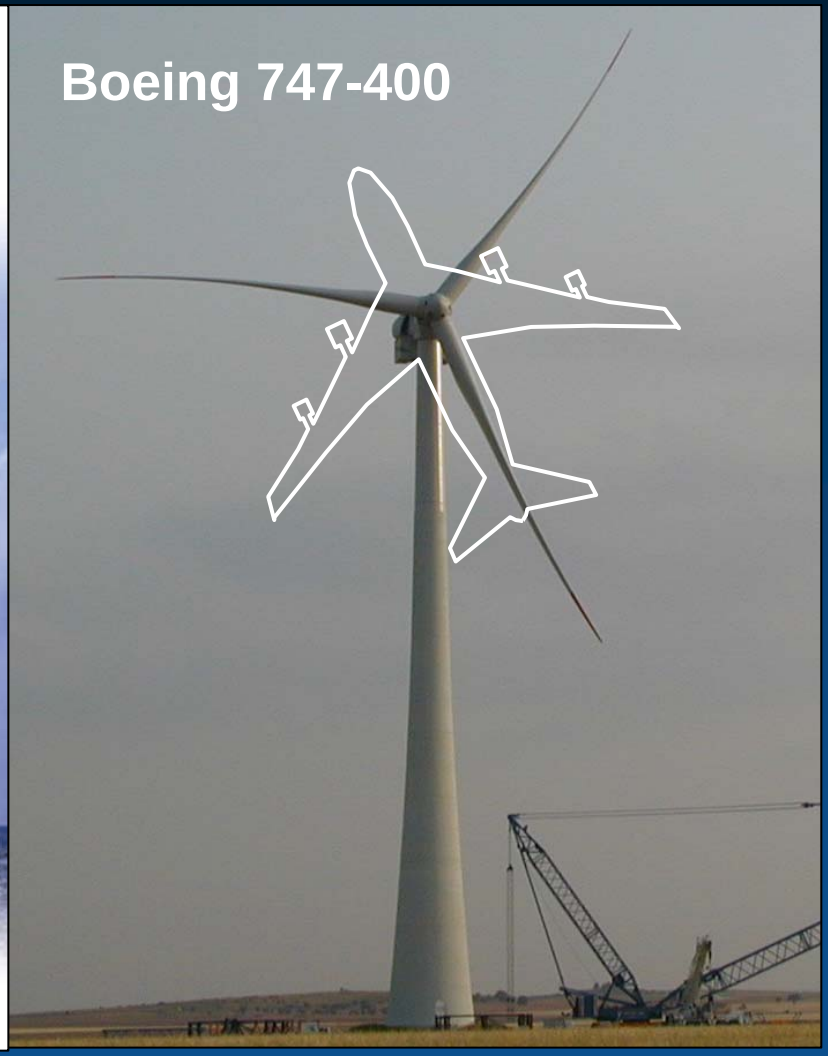




Evolution of U.S. Commercial Wind Technology



Offshore GE Wind Energy 3.6 MW Prototype



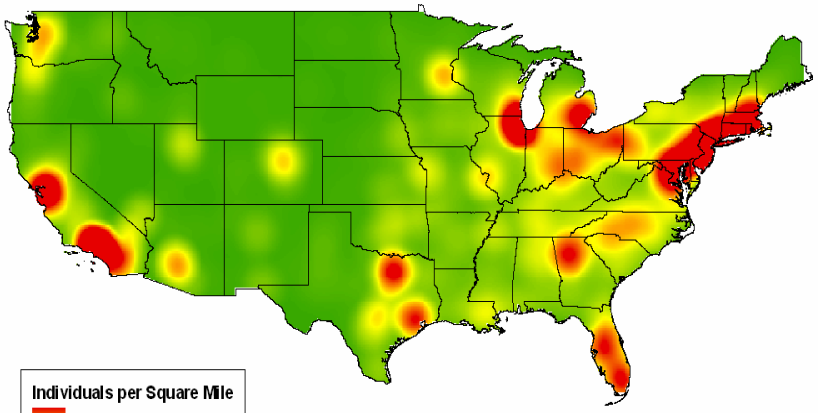
Offshore Wind – U.S. Rationale
Why Go Offshore?

Windy onshore sites are not close to coastal load centers

The electric utility grid cannot be easily set up for interstate electric transmission

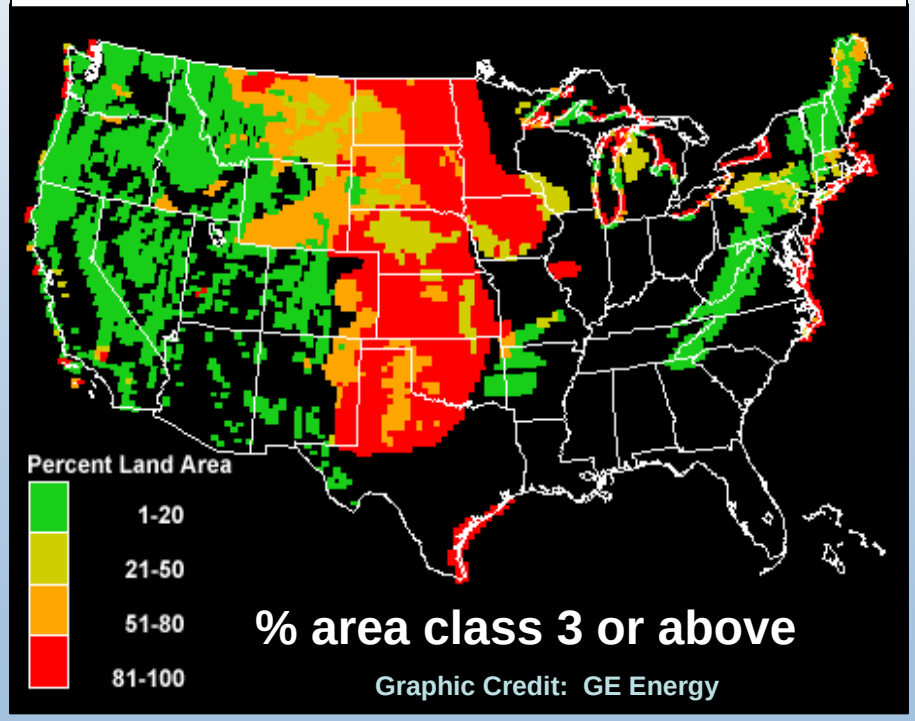
Load centers are close to the offshore wind sites

US Population Concentration

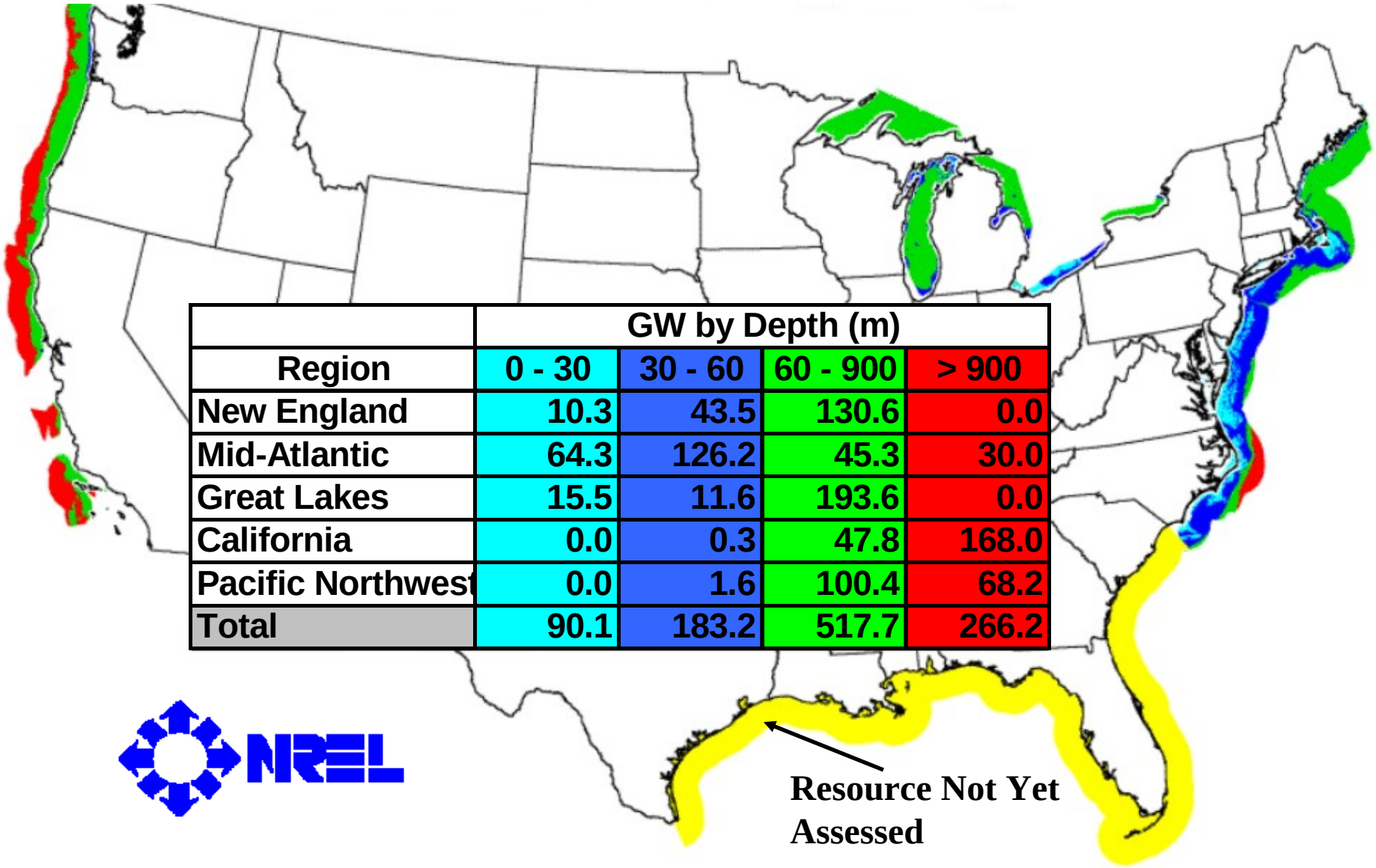


Graphic Credit: Bruce Bailey AWS Truewind

US Wind Resource



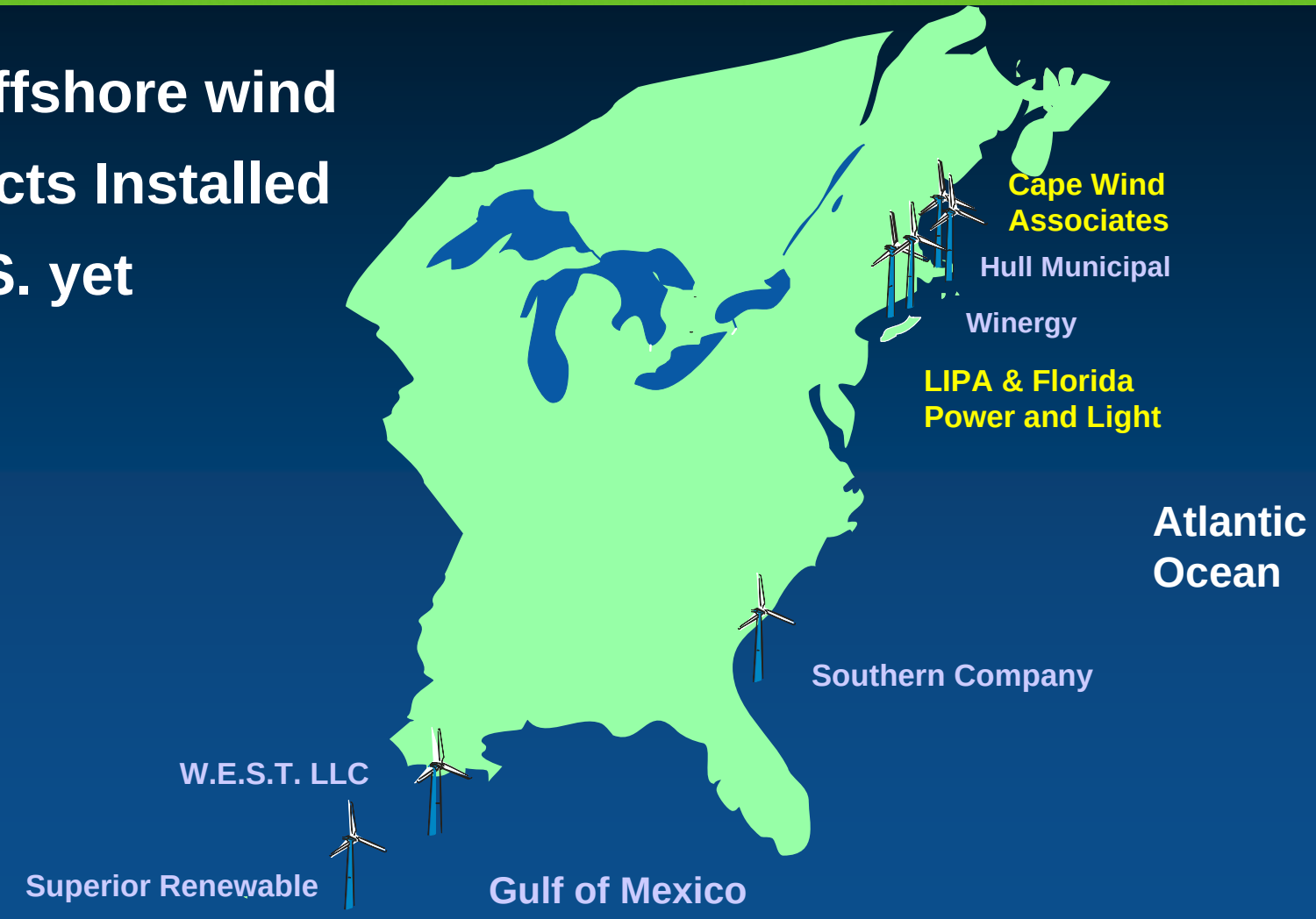
U.S. Offshore Wind Energy Resource

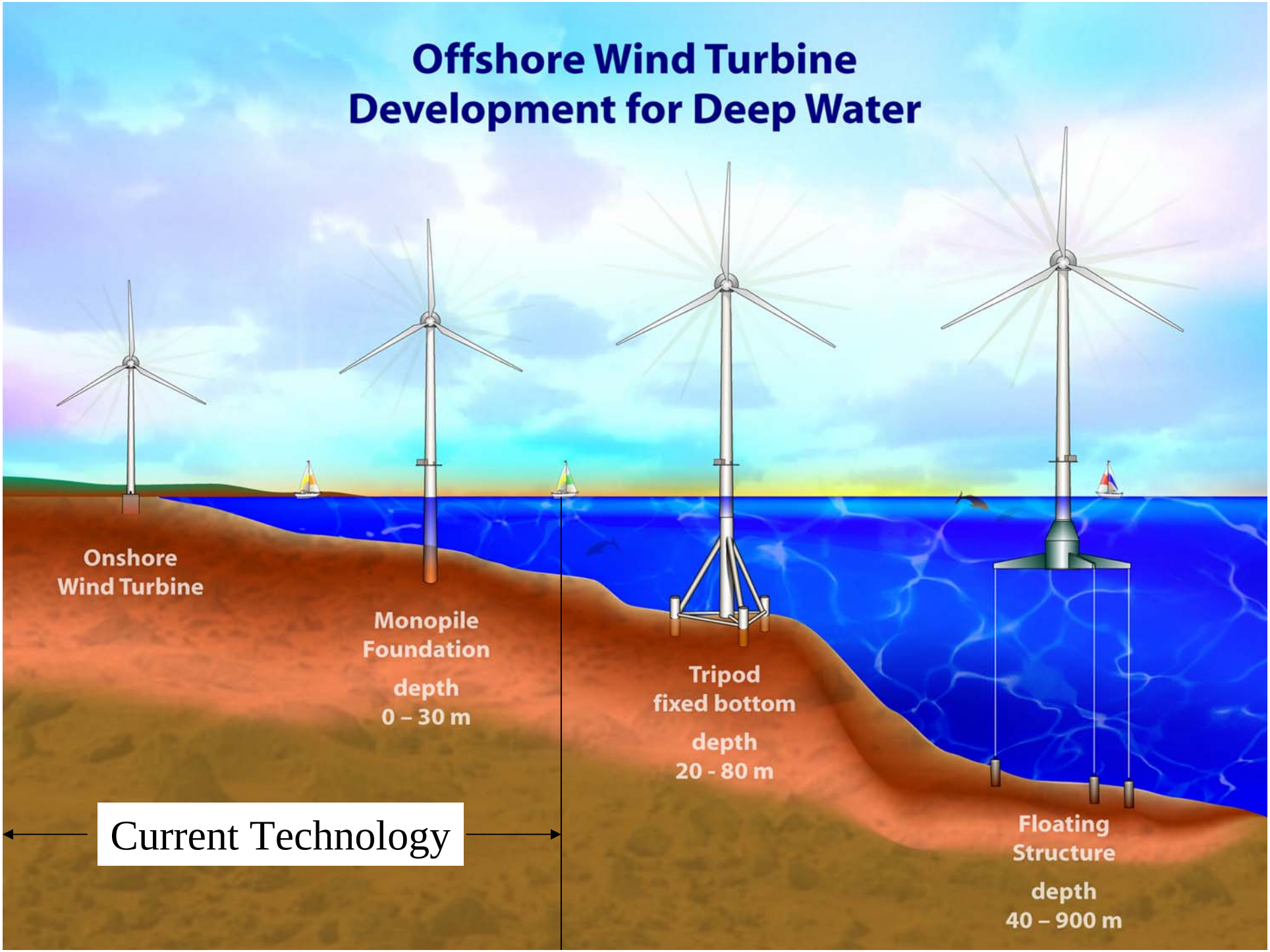


	GW by Depth (m)			
Region	0 - 30	30 - 60	60 - 900	> 900
New England	10.3	43.5	130.6	0.0
Mid-Atlantic	64.3	126.2	45.3	30.0
Great Lakes	15.5	11.6	193.6	0.0
California	0.0	0.3	47.8	168.0
Pacific Northwest	0.0	1.6	100.4	68.2
Total	90.1	183.2	517.7	266.2

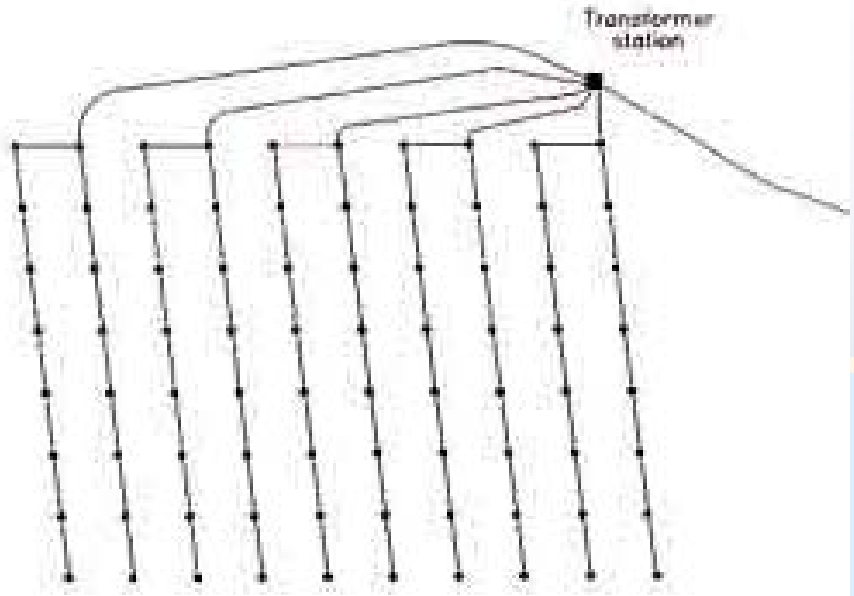
US Projects Proposed

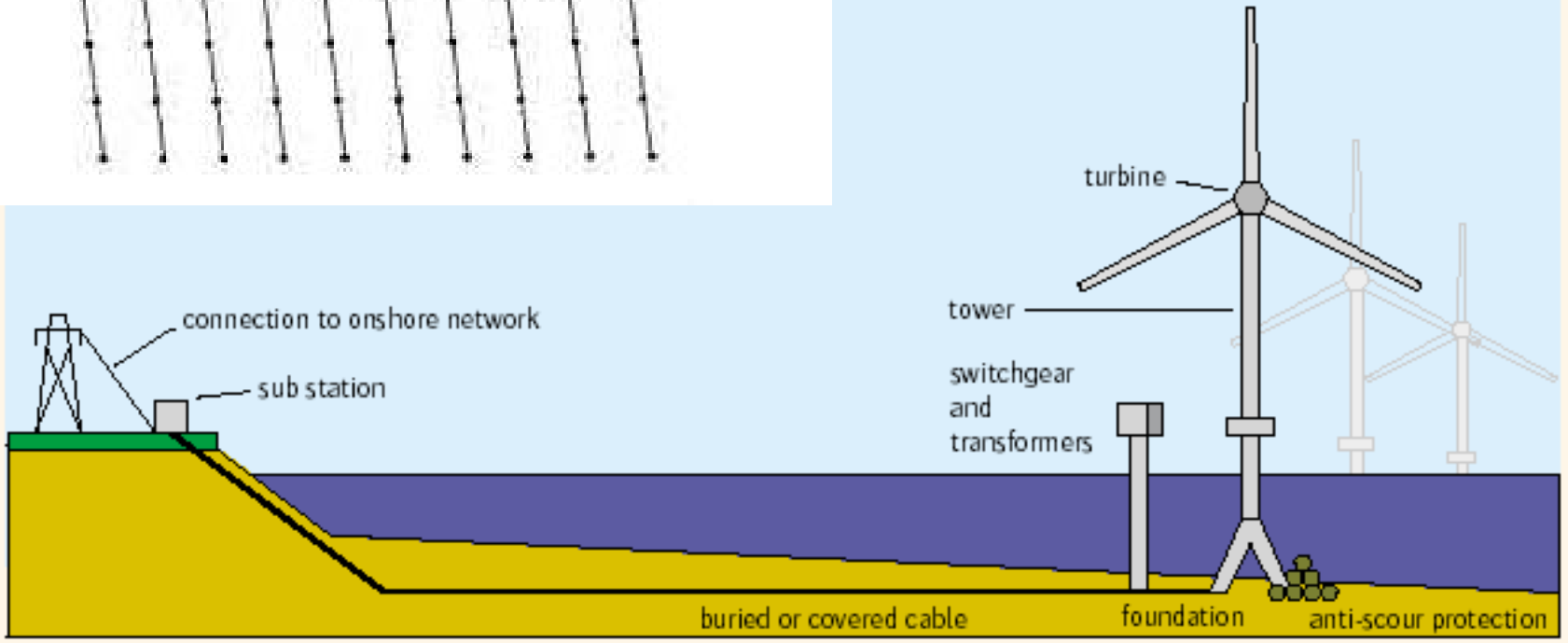
No Offshore wind projects Installed in U.S. yet




Offshore Wind Turbine
Development for Deep Water
Onshore
Wind Turbine
Monopile
Foundation
depth
0 – 30 m
Tripod
fixed bottom
depth
20 - 80 m
Floating
Structure
depth
40 – 900 m
Current Technology

Typical Offshore Wind Farm Layout





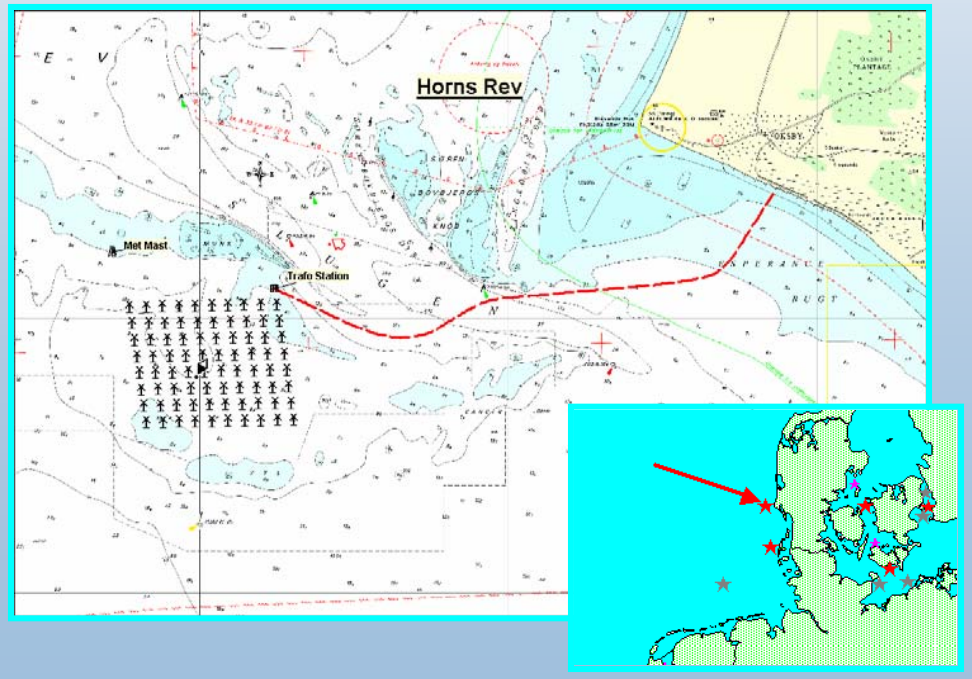
Location of Existing Offshore Installations Worldwide

Source: Wind Directions, September 2004

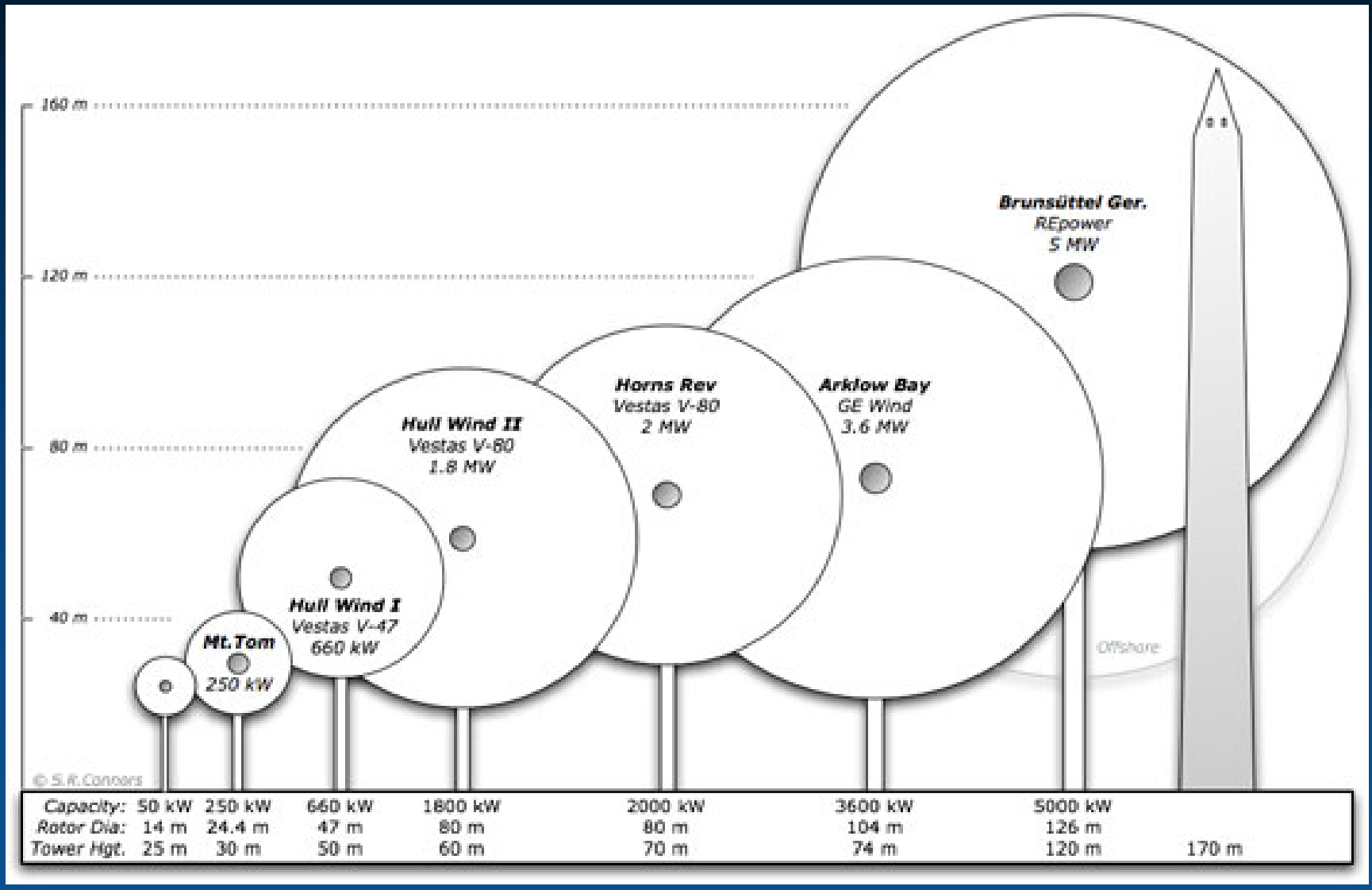
804-MW Installed Dec 2005

Horns Rev Wind Farm - Denmark

Country: Denmark
Location: West Coast
Total Capacity: 160 MW
Number of Turbines: 80
Distance to Shore: 14-20 km
Depth: 6-12 m
Capital Costs: 270 million Euro
Manufacturer: Vestas
Total Capacity: 2 MW
Turbine-type: V80 - 80m diameter
Hub-height: 70-m
Mean Windspeed: 9.7 m/s
Annual Energy output: 600 GWh

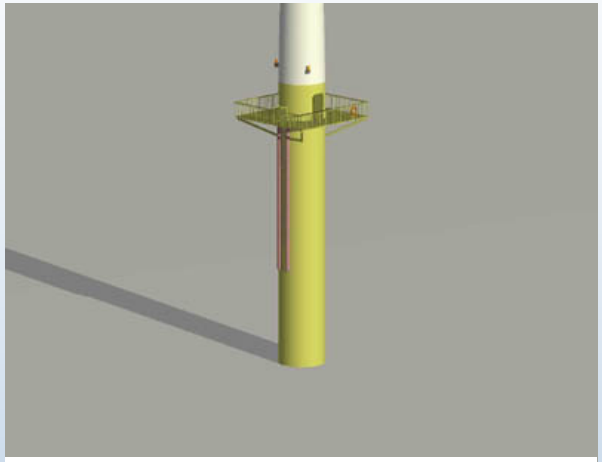


Wind Turbine Size



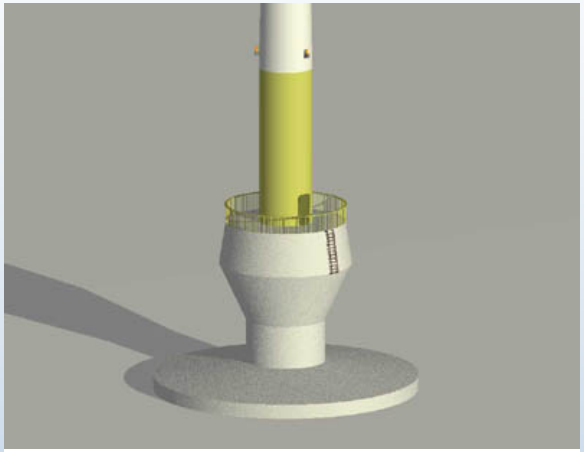
Fixed Bottom Substructure Technology

Proven Designs



Monopile Foundation

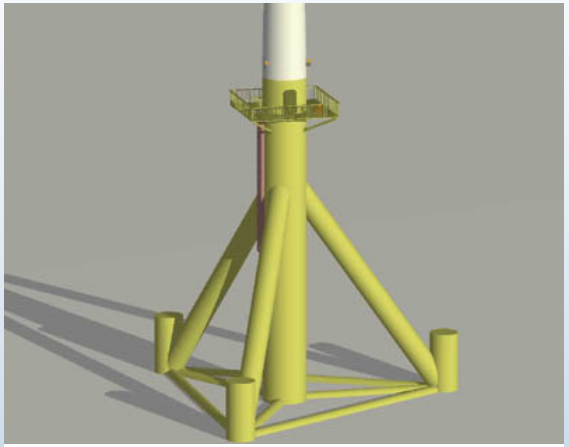
- Most Common Type
- Minimal Footprint
- Depth Limit 25-m
- Low stiffness



Gravity Foundation

- Larger Footprint
- Depth Limit?
- Stiffer but heavy

Future



Tripod/Truss Foundation

- No wind experience
- Oil and gas to 450-m
- Larger footprint

Graphics source: http://www.offshorewindenergy.org/

Arklow Banks Windfarm
The Irish Sea

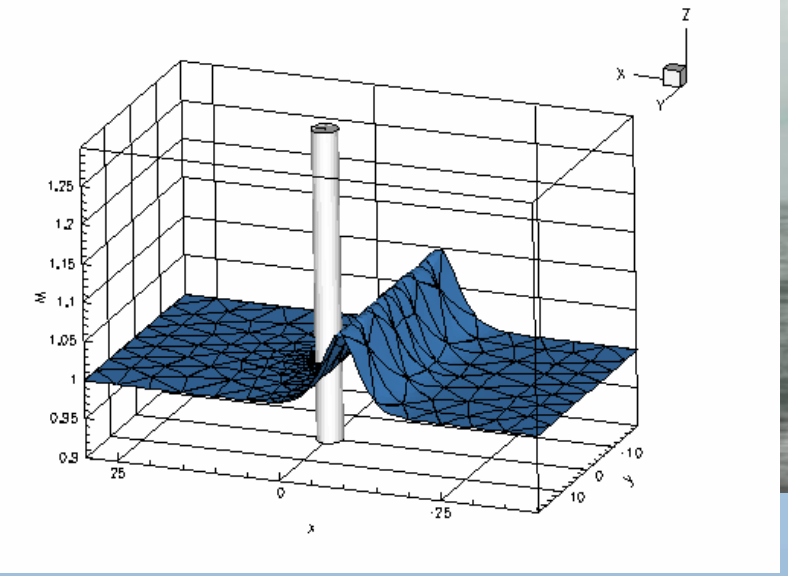
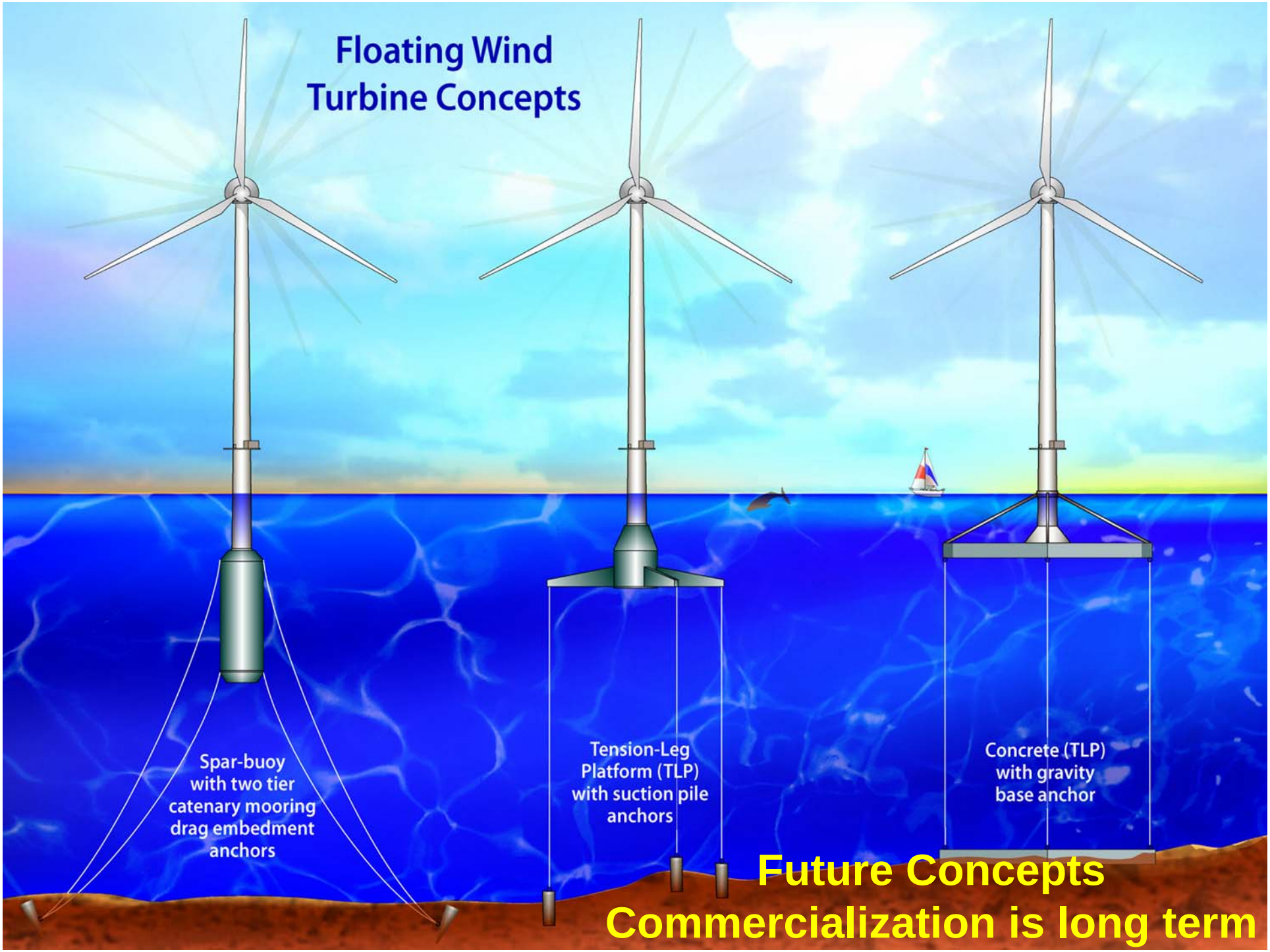
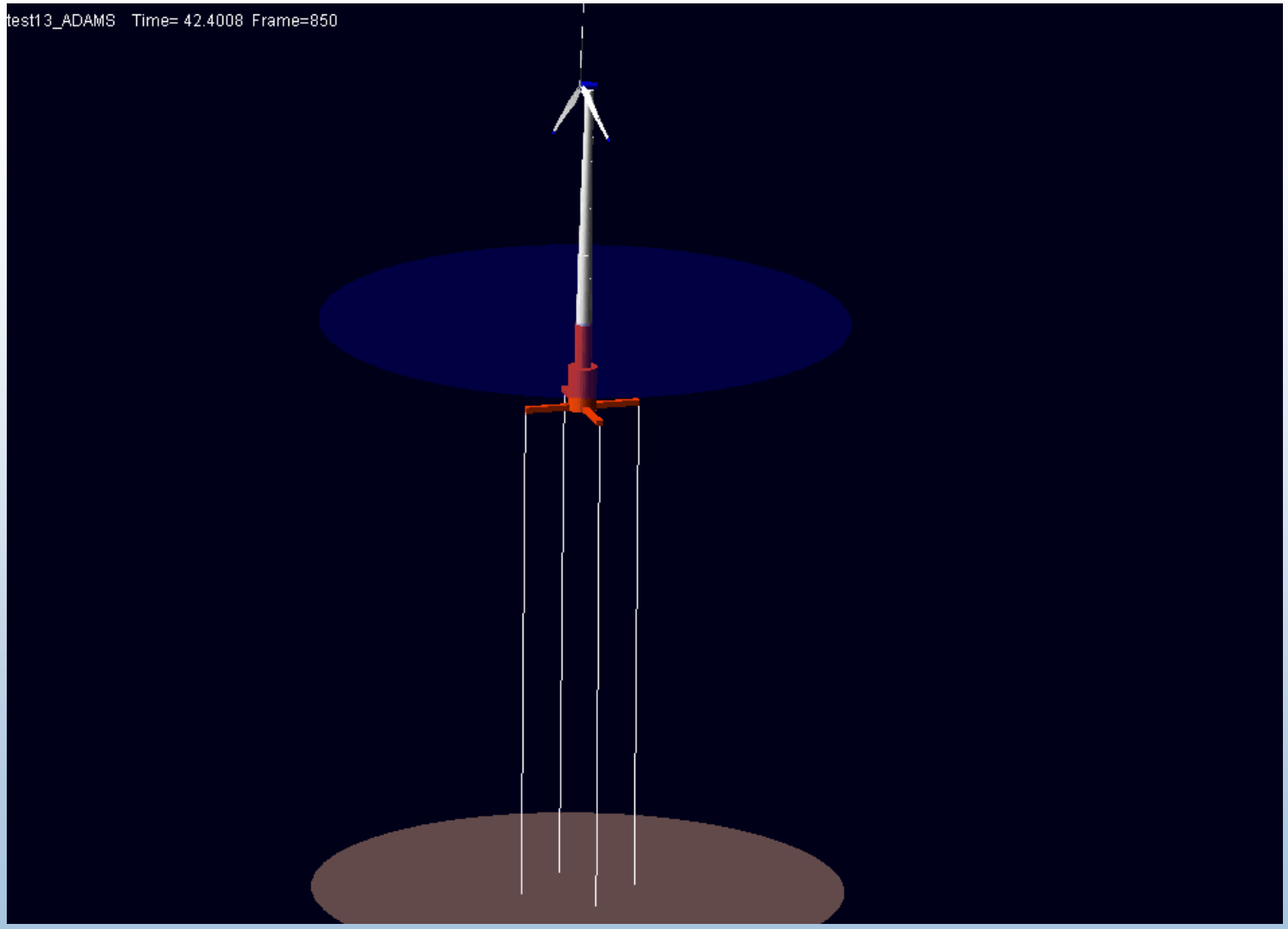
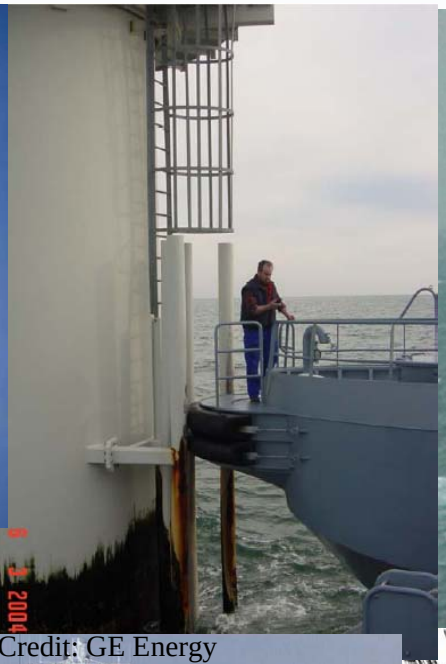


Photo: R. Thresher

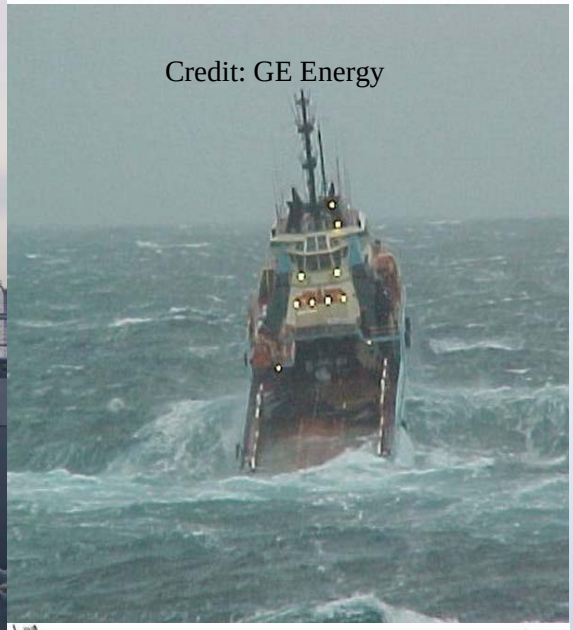

Floating Wind
Turbine Concepts
Spar-buoy
with two tier
catenary mooring
drag embedment
anchors
Tension-Leg
Platform (TLP)
with suction pile
anchors
Concrete (TLP)
with gravity
base anchor
Future Concepts
Commercialization is long term


test13_ADAMS Time= 42.4008 Frame=850

Offshore Wind Turbine Access



Credit: GE Energy



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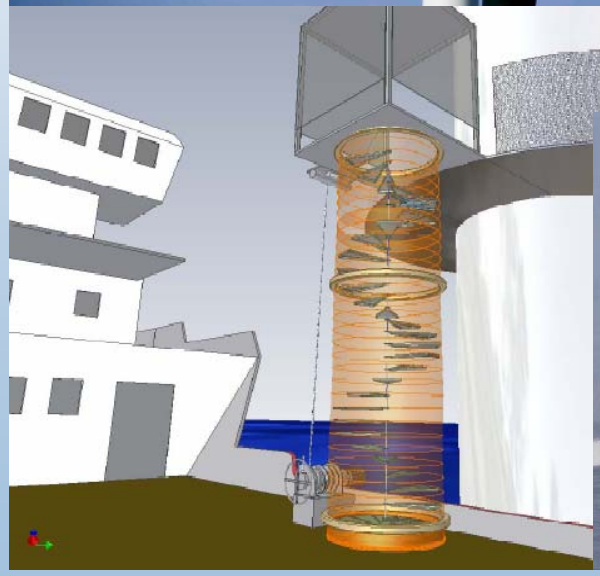
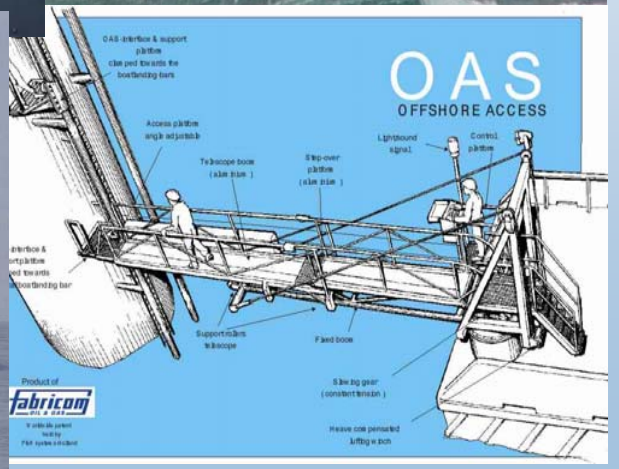
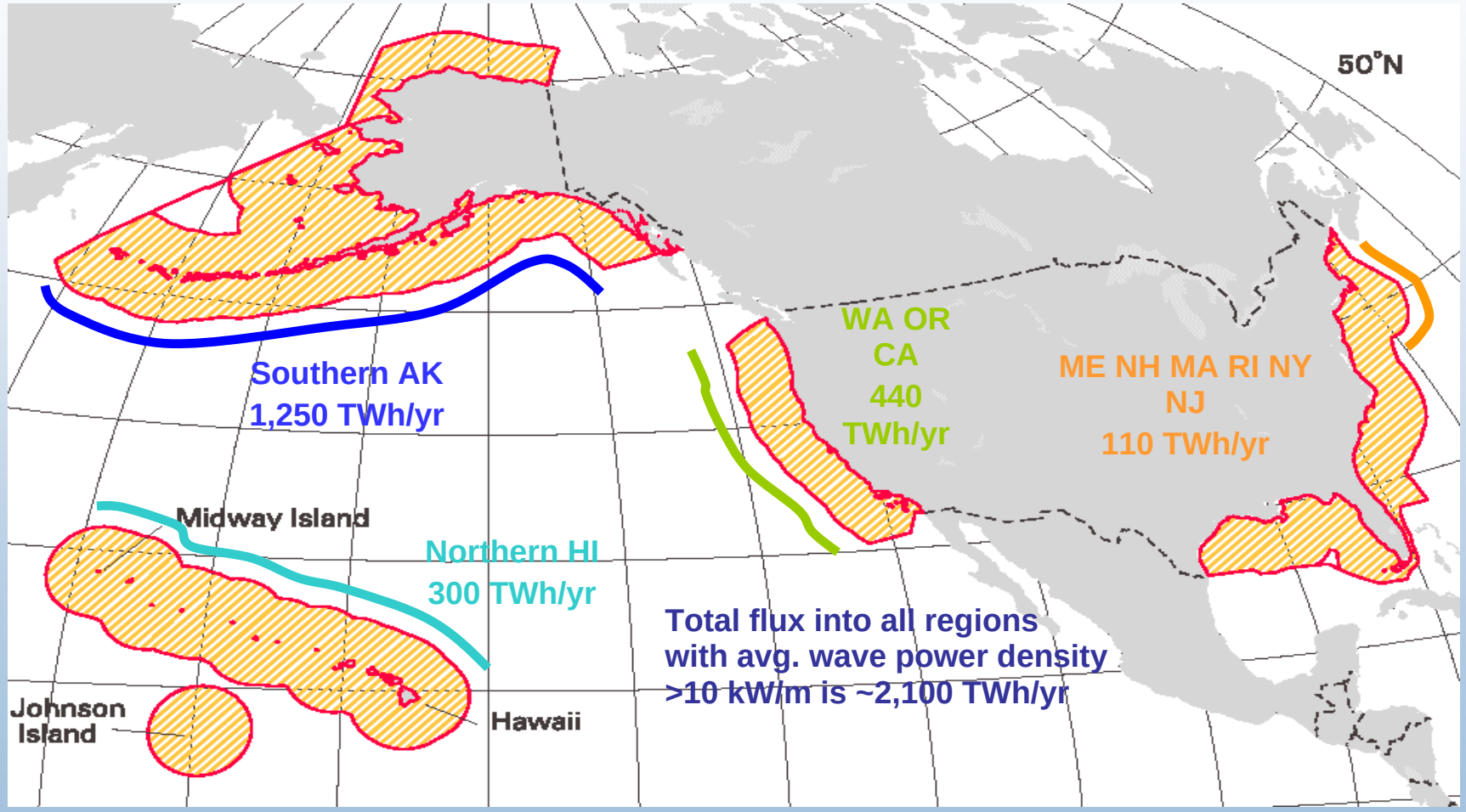




RePower 5-MW - Worlds Largest Turbine

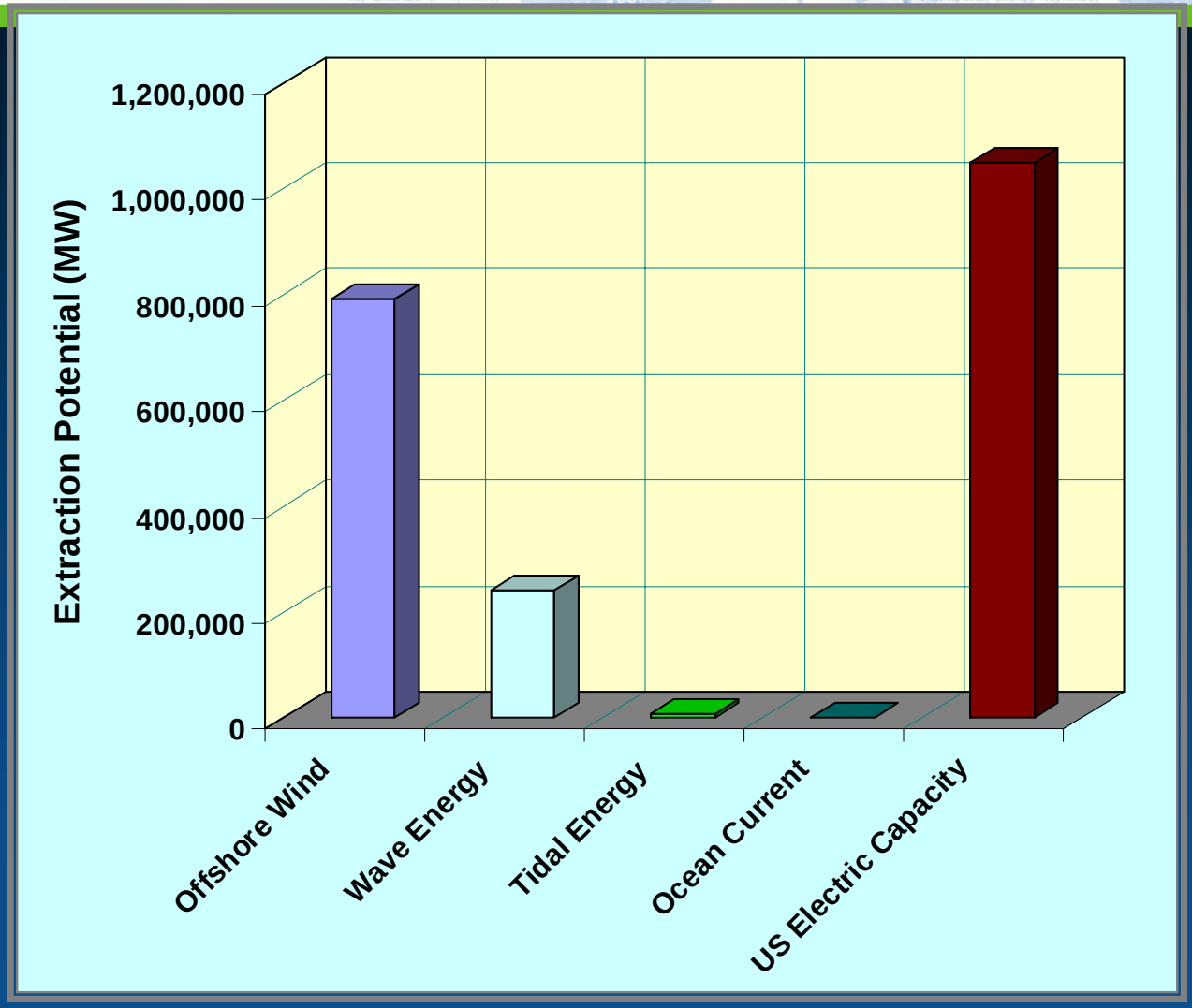
- 5-MW Rating
- 61.5-m blade length (LM Glasfibres)
- Offshore Demonstration project by Talisman Energy in Beatrice Fields
  - 45-m Water Depths
  - Two machines

Ocean Wave Resource Location



Harnessing 20% of offshore wave energy resource at 50% efficiency would be comparable to all US conventional hydro generation in 2003.

US Ocean Energy Extraction Potential

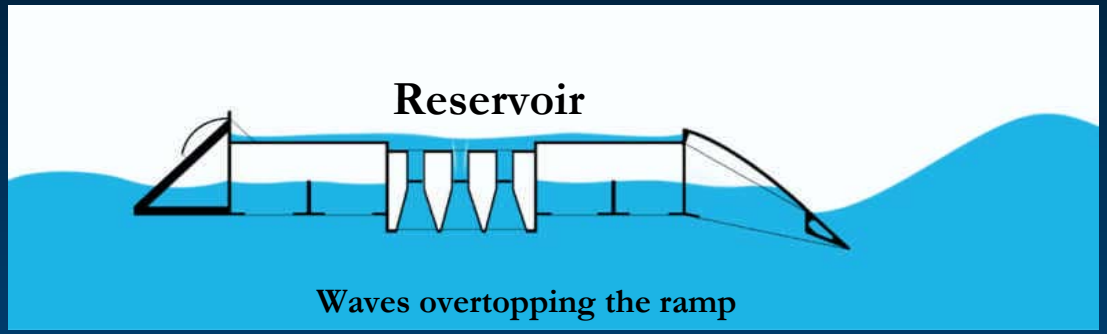


- Based on Typical Land-based Exclusions
- Offshore Wind
  - >Wind Class 5
  - 5-50nm
  - <900-m Depth
  - GOM, Alaska, Hawaii, SC, GA not included yet

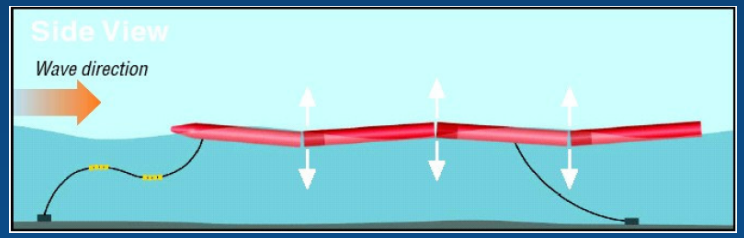
Wave Energy Extraction Technologies

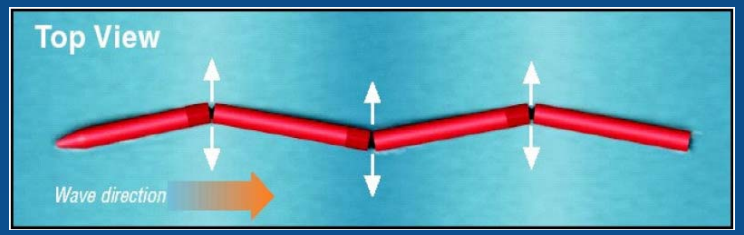
Point Absorber

Overtopping

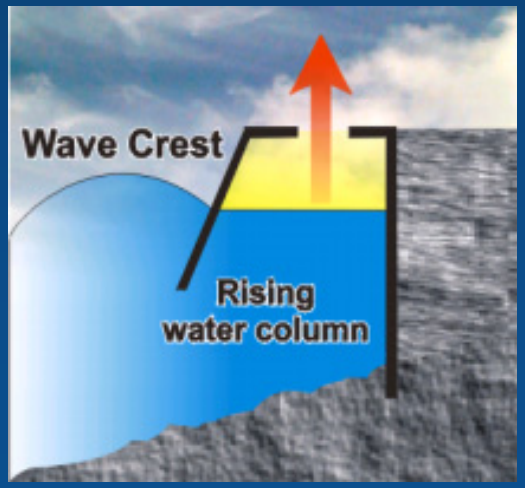


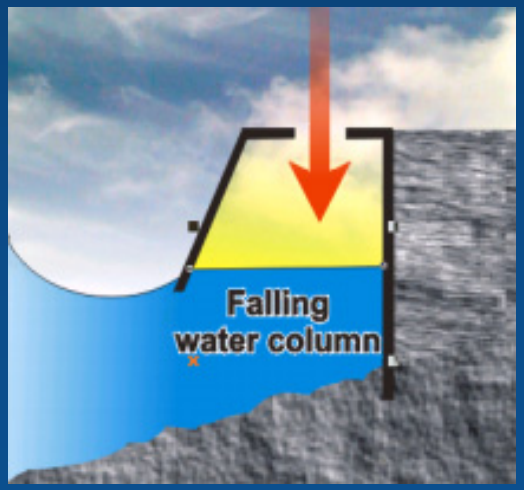
Attenuator





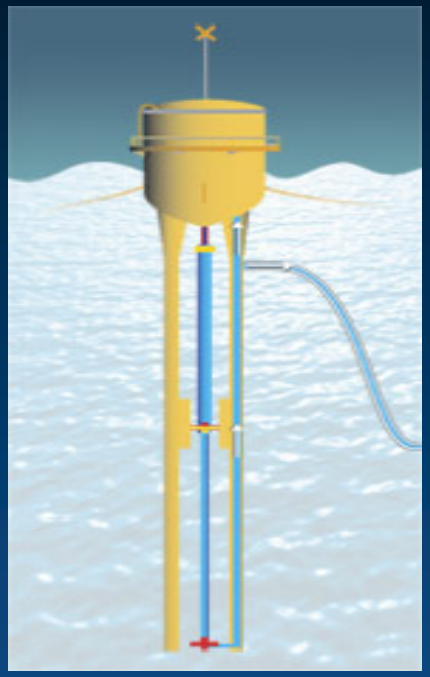
Terminator OWC



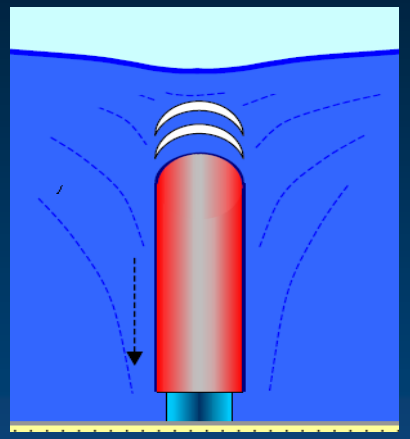


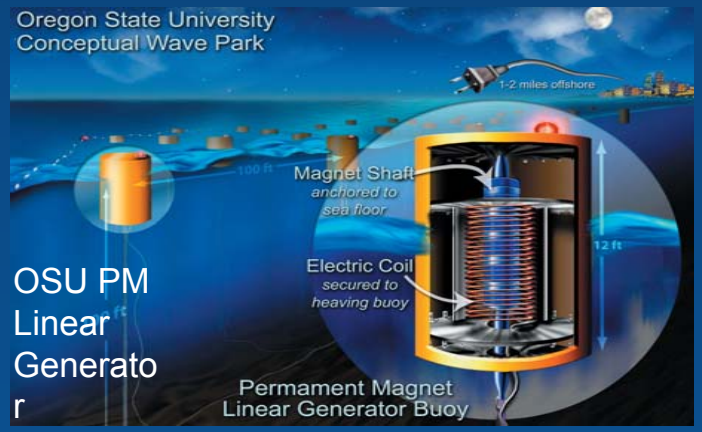
Wave (Point Absorber) Technology Examples

Aquabuoy; AquaEnergy - Makah Bay, WA



PowerBuoy; Ocean Power Technology Oahu, Hawai





OSU PM Linear Generator

Archimedes Wave Swing MK I - Portugal

Integrator Technology Example

OPD Pelamis Being Towed to EMEC For Test Trials

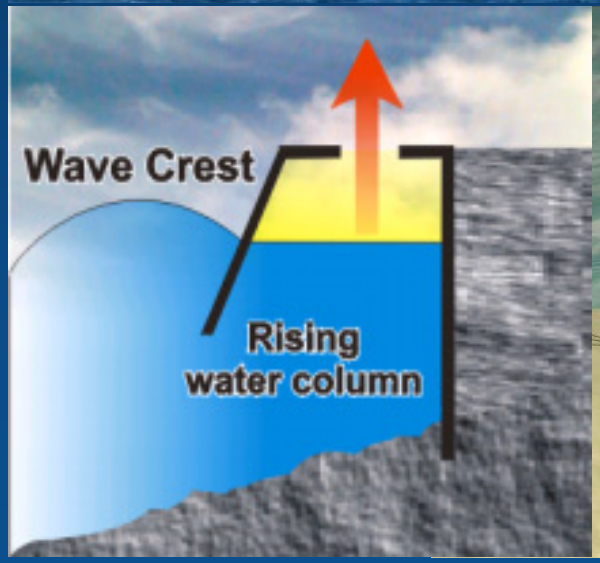
Terminator Technology Example

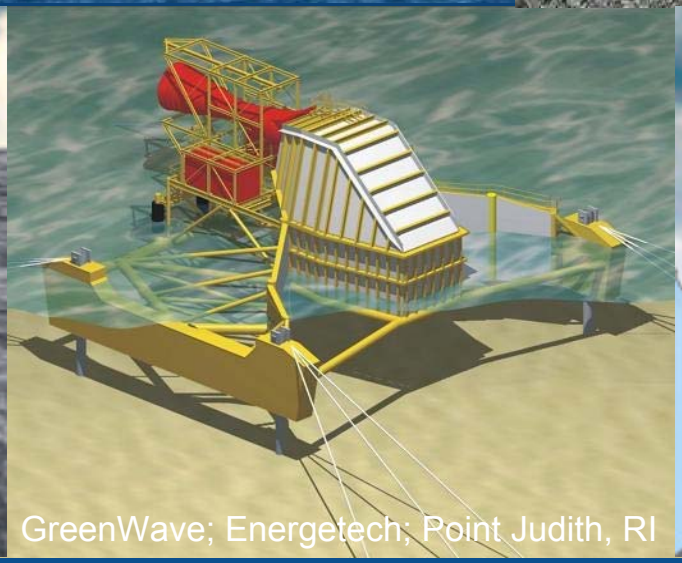
Wave Dragon 1:4.5 Scale Prototype Under Sea Test in Nissum Bredning, DK

Oscillating Water Column Technology

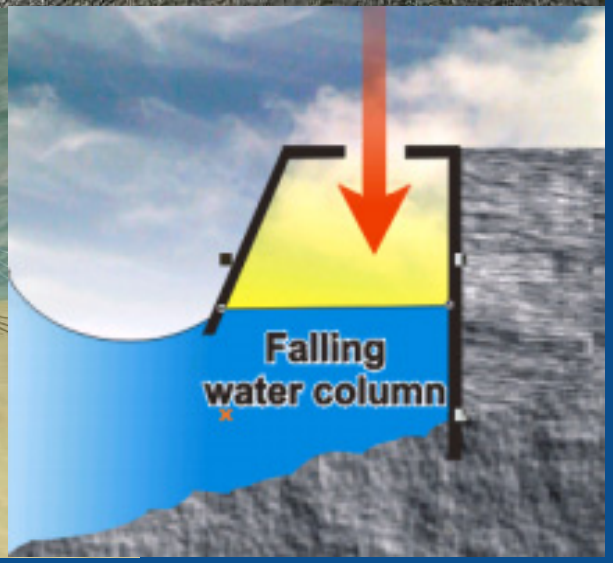
Oscillating Water Column; Energetech; Port Kembla, Australia

Wave Gen; OWC; Islay, Scotland





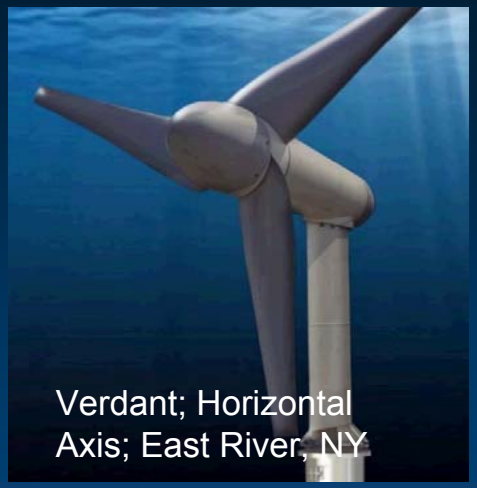
GreenWave; Energetech; Point Judith, RI



North America Wave Energy Projects "Coast to Coast"

	HI, Oahu Kaneohe	WA Makah Bay	RI Point Judith	CA, San Francisco	OR Gardiner
Developer	Ocean Power Tech	AquaEnergy	Energetech	SFPUC	Oregon State University
Development Stage	Deployed June 04	Permitting since 2002	Permitting since Feb 2005	Seeking funding for permitting	Seeking funding for permitting
Device	Power Buoy™	Aqua BuOY™	OWC	Pelamis (tentative)	TBD
Size	Single buoy 40 kW	4 buoys 1 MW	Single OWC 500kW	Single Unit 750 kW	TBD
Water Depth/ Distance from Shore	30 m 1 km	50 m 6 km	2 m 2 km	30 m 15 km	TBD

In-Stream Tidal Technology Examples



Verdant; Horizontal Axis; East River, NY

Gorlov Helical Vertical Axis; Merrimack River,

Hydro; Open Center Turbine; Gulf Stream

Lunar Energy, Rotech Tidal Turbine

Underwater Electric Kite; Merrimack River,

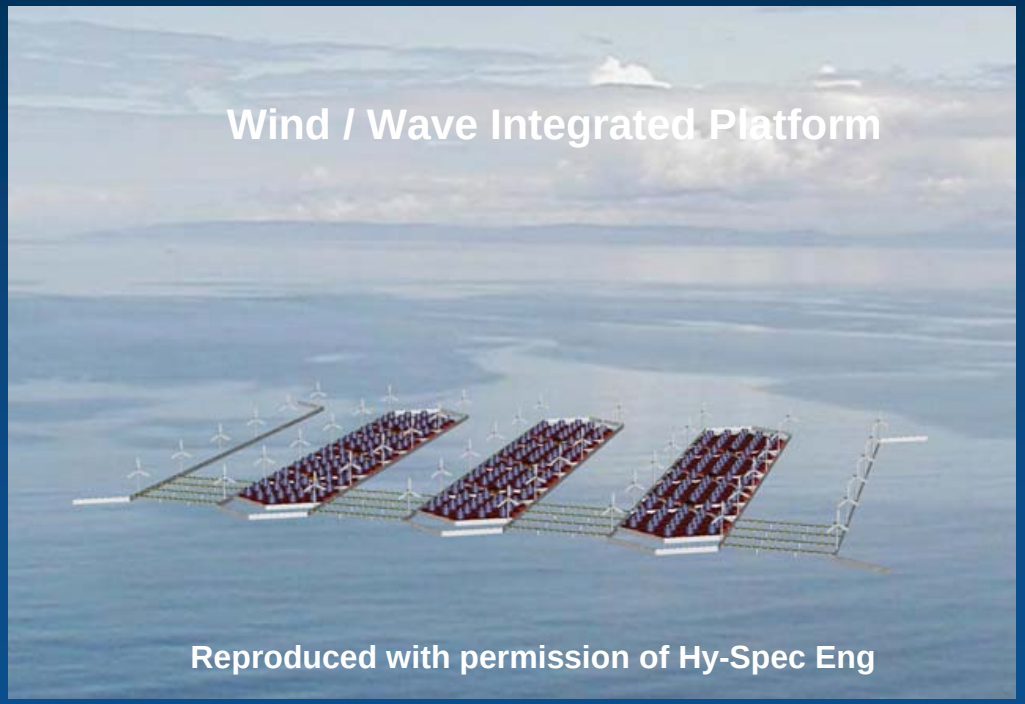
MCT SeaFlow Experimental Test

North America Tidal Energy Projects "Coast to Coast"

	MA Amesbury	NY NY, East River	BC Race Rocks	CA, SF	DE Indian River Inlet	WA Tacoma
Developer	Verdant	Verdant	Clean Currents	SFPUC Marin	UEK	Tacoma Power
Development Stage	2 Month Test Complete	Construction	NA	Formative	Permitting	Application in process
Device	Vertical axis	Horizontal axis	NA	TBD	Horizontal axis	TBD
Size	1m X 2.5 m 1 unit	5 m diameter 6 units	NA	TBD	3 m diameter 25 units	TBD
Power (kW) at Max Speed (m/s)	0.8 kW @ 1.5m/s	34 kW @ 2.1 m/s	NA	TBD	400 kW @ 3 m/s	TBD

Offshore Wind / Wave Synergy

- Long term possibility
- Maximize Grid Interconnect Potential
- Improve Intermittency & Total Energy Output
- Increase System Reliability & Reduce Maintenance



- Credit: GE Energy

Summary

- Near term wind turbines in shallow-sheltered sites possible now.
- New wind technologies for deeper water are long term
- Ocean wave and current technologies are in the first prototype testing stage
- Hydrogen production – long term